Mechelecív

Volume 24 March - 1966 No. 4

THE GEORGE WASHINGTON UNIVERSITY

MARCH 1966

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WHAT ARE YOU SELLING?

Last issue, on this page, we entered into a little philosophical discussion on the problem of Motivation for engineering students and the esthetic emotions which impel the struggling student toward his glowing goal of professional excellence. This time let's loosen our ties and say a few words about the greatest little motivator known to modern science — money. You may smoke if you wish (although it may be hazardous to your health).

Let's be honest with each other, at least for the time it takes to read this page, just to see how it feels. The real reason that we go to college is to bluff our way to a degree which will enable us to live in the style to which we would like to become accustomed. An engineering degree is a nice little meal ticket and while crass monetary renumeration is rightfully scorned as a reason for academic questing, it does pay the liquor bills.

Have you ever in a moment of temporary sanity, wondered why anyone would be willing to hire you after your mind has been sufficiently bent to get your first degree? Just what miracles is your future employer going to expect of you that will justify his handing over a king's ransom to you every payday? Just what commodities will you be trying to sell on the wide open manpower market?

The answer is that the graduate engineer is selling "problem solving". Your future boss is buying your ability to apply all the resources you've developed in college; Mathematics, Physics, Economics, humanities and all your technical knowledge, to solve his problems. Part of this ability is knowing which question to answer. An approximate answer to the right question usually beats an eight place answer to the wrong question. He's also going to be paying for your ability to communicate to him the answers to his questions. Without a logically written narrative development the most brilliant of your thoughts will sparkle like a soggy sneaker.

If you develop these qualities you'll be hired and be payed for your efforts in a rather pleasing manner. If however, you add a few other tools to your brief case — the ability to make decisions, to plan thoroughly, to question the accepted, to deal with people in a mature way and to develop an aggressive dissatisfaction with mediocracy — you'll become a legend in your own time, earn so much money you'll be forced to find a woman to help you spend it and you may even be worthy of the title Engineer. Now is the time to pause and decide which qualities you want to sell.

mec

Required reading for this period is Dean Mason's letter "IF", written for the Special Engineers' Week edition. It is reprinted in this issue in the hope that as many students as possible have an opportunity to read this excellent expression of one engineer's philosophy.

the Mecheleciv
VOLUME 24 MARCH-1966 No. 4

ARTICLES

page

DEPARTMENTS

COVER

This month's Mecheleciv cover symbolizes the bursting forth of a young engineer. Let's hope he isn't snuffed out.

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PHYSICS. Solid state (basic and applied) . . . electromagnetic propagation . . . upper atmosphere phenomena . . . superconductivity and cryogenics (Ph. D. graduates only).

MATHEMATICS. Statistical mathematics . . . matrix algebra . . . finite fields . . . probability . . . combinatorial analysis . . . programming and symbolic logic.

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Dean Martin A. Mason

"IF" --

There is a pleasant fantasy in which one sometimes indulges as the years grow fat and the energies lean -- it is the "IF" game. You know it as, "If I were rich --", or "If I were smart --". At my age it has to be "If I had it to do over --". "If" is a fantasy with a certain reality deriving from revelation of what might have been. But that makes the game a little different from pure day-dreaming, and as a result some benefit infrequently comes from the playing of the game. There is one little bias in the rules though -- always the game is played with hindsight, and the more hind the clearer the sight.

So -- here goes -- and if I am changed in your eyes after the reading, you will at least know more than you did before the reading, and may yourself be bigger or smaller someday than if you had not read.

If I had it to do over -- I would be an engineer. In my thirty-five years of being an engineer, since I left G.W.'s hated walls of green paint without attending convocation to receive my B.S.E., satisfactions have far exceeded disappointments, in accomplishment, in money, and in status. I am today more convinced than ever that ultimately it will be engineers who will solve mankind's problems. People are fine, I like them, but engineers are special -- in their outlook, attitudes, commitment, and dreams. I'm proud to be an engineer.

If I had it to do over -- I'd be different in my approach to my responsibilities in society. I think I would raise my voice oftener and louder against society's simple-minded ignoring of facts when facts might require society to sacrifice comfort, or convenience, or profit, or position. I know I would be more active in supporting my conviction that government, at any level, is too important to be left exclusively to politicians and pressure groups, and must include more engineers. My concern now is that too often, because I felt some ignorance, I didn't take a stand when it might have made a difference only to discover that my ideas could have been a contribution. As an engineer I'd recognize better that it is my duty, not theirs, to find ways to make others see and use my special talent. Let's get off this subject -- I'm getting uncomfortably close to believing others are right in saying engineers are self-centered, and I know now they must not be.

If I had it to do over -- I'd be a different student than I was. I'd search diligently for ways to find out more about more things than I did. I'm sure I would rebel against the professor who repeated the text in class or considered my assumed brains to be a sponge, or who didn't make me think whether I wanted to or not, or who didn't treat me as responsibly as he demanded I treat him. (Incidentally I know now the secret way to rebel -- I'd quietly learn more on my own about the subject than he knew and then start discussion in class.) I think I would have more concern for what I knew and was learning than for the grades I would get. As a fact I don't remember a single grade in any course I ever took and no one has asked me since graduate school except once a consulting client implied (incorrectly I hope) I had gotten an F in calculus when I didn't explain clearly the differential equation in the report I sent him. I think I would be much more concerned about organizing intelligent informed appraisals for argument before constituted authority. I know now I should have stood up and been counted when I "knew" I was right, and taken my bumps when I was proved to be wrong, because thus I would have learned earlier and with fewer bruises that it isn't enough to "know" I am right, I have to be able to prove I am right. I'm sorry I didn't expend more effort to imprint more of me on my schools through activities and through doing things I believed needed to be done.

If I had it to do over -- I would ration the time devoted to technical things, so I would have time to develop my knowledge of and stature in the other things that affect my life. And I'd plan this development to explore many things, rejecting none until I had enough of a taste to make a sound decision. I still don't like politics, or the intellectual snobbism of "the Arts", but I know enough why I don't like them to argue the merits and demerits of the attitudes, and to respect, without admiration, their positions. Had I but known better I would have worked much harder at understanding why a person thought and acted as he did, so that I could maneuver him to my side rather than confront him as an adversary.

If I had it to do over -- I'd be more interested in experience than security, for the first ten years of my career. I learned many things (still am learning, in fact) late rather than early when they could have improved me, my career, and my contributions, because I was reluctant to take a risk (the Great Depression of the '30's is my excuse, but the Great Society of the '60's may be just as good an excuse as you look back). I think I would have more confidence in myself while young and stretch a little harder and farther to get more quickly what I thought I wanted.

If I had it to do over -- I would work harder when I worked and relax more when I relaxed, but I'd put them in better balance. I know now that satisfaction comes from more and harder work of my choice, from accomplishment and not from leisure. In my early years in the profession I would have worked constructively more and learned earlier that meaningful relaxation is as much fun as time-consuming idiot play. Today I know the truth in the statements that "whatever you do -- do it well", and "don't just talk, do something". If only I had known then that play is really excited interest in something and that it can be as constructive as work!

If I had it to do over --I would choose what I did more because I liked to do it than because it paid more or was convenient at the moment. What curiosities I might have satisfied, how much more I would know, perhaps I might even have discovered the reasons why I am looking back as I am now.

And so I reach the end of this fantasy, realizing that as I read it in print on a later day, I will think if I had it to do over -- what?

ON ATOMS AN

Tom Tinley has recently graduated from G.W.U. for the second time, receiving his M.S. in February, 1966. He received his B.M.E. in August, 1964 and is now working toward the Doctor of Science degree while on a National Science Foundation traineeship. While an undergraduate, Tom was active in Sigma Alpha Epsilon Fraternity and Tau Beta Pi Honor Society.

INTRODUCTION

I am sure that at one time or another most engineers have been intrigued by the possibility of predicting the properties of materials from a purely theoretical analysis of their atomic composition. I am equally certain that those who have considered the complexities involved in making the most primitive predictions have dismissed the possibility of much progress ever being made in the area.

Although the difficulties are rather severe, physicists, and even some engineers are working and making some progress in this area. This article presents a qualitative description of one small facet of this work; namely that of calculating the thermal variation of the elastic constants of a monovalent metal single crystal. Since all solids are composed of atoms, such a description, as specialized as it may sound, involves many of the elements contained in all calculations of elastic material behavior based on an atomistic approach.

ELASTIC CONSTANTS

Before describing the atomistic approach employed in the present calculation it may be well to discuss elastic constants briefly. Elastic constants are analogous to ordinary spring constants which we have all dealt with in physics, i.e., they indicate the ratio of force required to maintain a certain deformation, to that deformation (be it in terms of strain, ϵ_{ij}, or displacement, x).

For an isotropic material, most engineers probably recall that Young's modulus, and Poisson's ratio are the only two elastic constants required to describe completely the relation between an arbitrary stress and strain. In the case of the single crystal with a cubic structure considered here, the general idea is the same. However, due to the fact that the atoms are arranged in rows and planes the material is not isotropic and, therefore, three elastic constants must be considered for a complete stress strain description. It is found that all elastic constants decrease approximately linearly with increasing temperature. The purpose of this article is that of indicating the method of calculating this decrease.

METHOD OF CALCULATION

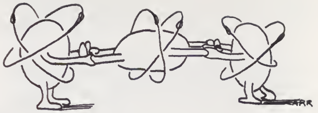
Having refreshed the idea of elastic constants, it is next appropriate to consider a general method for their calculation which may be employed in the present atomistic analysis. To show formally how this method is developed would be a rather lengthy process, therefore only a simple spring will be discussed here. The results may then be generalized to the case under consideration. Recall that by integration the stored energy of a spring may be found as $1/2kx^2$. Conversely, if it is assumed that the energy is initially given in this form, it is apparent that k may be found by differentiating twice with respect to x. Generalizing this idea it may be shown by a thermodynamic analysis that if the Helmholtz free energy, F, of an elastic body is known in terms of strain, any elastic constant may be found by taking the second derivative of F with respect to its individual strain components (at constant temperature). Since F may be expressed as the sum of a temperature dependent term and one independent of temperature, the thermal variation of elastic constants may be determined by differentiating only the latter. Differentiation is rather straightforward, therefore the problem of finding elastic constants from an atomistic approach reduces, in this case, to determining the thermally dependent part of the Helmholtz free energy of a crystal, from a consideration of atomic interactions, and then the change in this energy when the crystal is strained (i.e., one must find $F(\epsilon_{ij})$).

ATOMIC MODEL

Having clarified what we are looking for (three elastic constants) and, in general, what is

ELASTIC CONSTANTS

by Tom Tiney



required to find them ($F(\epsilon ij)$), we now may proceed by focusing attention on the atoms of a crystal lattice. For this purpose it is helpful to have an atomic model of the crystal in mind. A rather good model is that of a cube made up of hard spheres bound statically (for the moment) together by springs attached to all of the spheres. The springs, of course, represent the often complex, and still to some extent unknown, interactions between the atoms. Enough springs must be included in the model to take care of most of these interactions. (It may appear that the springs will not adequately represent the complicated interatomic forces, but, as will become apparent later, for the purpose of this analysis they suffice.)

In order to write the free energy as a function of strain for such a model, the equilibrium energy is assigned the value of zero due to the fact that only the change in energy with strain is of concern. Next, since it is known that in the present case the change in energy of the crystal is due to a change in the relative positions of the atoms, these positions are expressed explicitly in terms of strain. This may be done from purely geometrical considerations by drawing a model of the specific crystal structure of concern in its unstrained state, and then imagining that certain strains are imposed on it. By choosing a general reference atom, drawing a vector from it to each of its neighboring atoms, and subtracting each undeformed vector from its deformed counterpart, the desired displacements in terms of strain may be found. Of course, since the form of the energy has been implicitly assumed to be quadratic in strain, the relative displacements need only be found to that degree of accuracy.

TOTAL ENERGY

Referring again to the model it is seen that when the position of a single atom relative to the rest of the atoms is known as a function of strain, the amount of stretch and the associated change in energy of each spring is also known as a function of strain. By summing over all of the springs attached to each atom and multiplying by the number of atoms (then dividing by two to avoid counting each spring energy twice), the total energy as a function of strain can be found. Finally by simple differentiation the desired elastic constants can be found.

In applying this to a real crystal, the same approach will work if the effective spring constants between atoms are known. It may also be apparent that all details of the interatomic forces need not be known since (for infinitesimal strains) the form of the interaction energy must be some constant times the square of the change in relative displacements. (In metals the electron gas somewhat limits the validity of the spring and sphere model.)

THERMAL VARIATION OF ELASTIC CONSTANTS

Thus far, in order to maintain some simplicity in the discussion, no mention of temperature has been made when referring to the model. Thus, the variation of the elastic constants with temperature has been ignored. In fact, what has been discussed so far is restricted to a theoretically absolute zero temperature. In order to allow for thermal variations of any properties of the model we must pluck it so as to set the spheres into chaotic motions. These motions, or lattice vibrations, exist constantly in a real crystal and change as a function of temperature. Through the change in energy associated with these vibrations, the elastic properties of the crystal are altered.

The central problem then, in determining the temperature variation of the elastic constants, is that of determining the vibrational free energy of the crystal lattice as a function of temperature and strain. By simple differentiation, as discussed previously, the desired quantities are then obtained. In the case of a real atomic lattice the analysis of the vibrations is nearly identical

(Continued on page 10)

to that which may be applied to our model, so the model again serves well. Therefore, with the model as a reference the analysis may now proceed.

First, it is assumed that the potential energy of the unstrained crystal lattice may be expanded in a Taylor series to second order in the displacements of the atoms (vibrational displacements, not strain displacements) from their equilibrium positions. The general form may be reduced to

$$V = \frac{1}{2}\sum_{ij} C_{ij}\, x_i x_j$$

where C_{ij} may be associated with the spring constants of the model (or viewed as second derivatives with respect to x_i and x_j), and x_i is the displacement of the i^{th} atom from its equilibrium position. The sum extends over all i's and j's.

Employing Newton's law,

$$F_i = m\ddot{x}_i = -\frac{\partial V}{\partial x_i}$$

we may write the equations of motion for each atom immediately. However, this would result in 3N coupled equations (where N is the number of atoms in the crystal) due to the cross terms in V. To avoid this disaster we define a transformation to an abstract set of coordinates (normal coordinates), $\mathcal{E}_i$, such that when the potential energy is written in terms of $\mathcal{E}_i$ the result is

$$V = \sum_i \omega_i^2 \mathcal{E}_i^2$$

(The details of this transformation are not important to the article, so just believe that it is legitimate.)

In terms of the new coordinates it is found that the equations of motion are uncoupled, in the form

$$\ddot{\mathcal{E}}_i + \omega_i^2 \mathcal{E}_i = 0$$

and there are 3N of them. These equations may be recognized as those of harmonic oscillators where ω_i^2 is the oscillator frequency. Thus what has been indicated is that the original chaotic motion may be reduced to the motions of 3N independent harmonic oscillators.

In order to solve for the elastic constants it only remains to find the energy of each oscillator, sum the individual energies to obtain the total vibrational free energy of the crystal, express the energy in terms of strain, and finally differentiate twice to obtain the part of the elastic constants due to the vibrations.

In order to find the individual energies of the oscillators we must enter the murky realm of quantum mechanics. Omitting details, the energy of the i^{th} oscillator is found to be

$$E_i = \hbar\omega_i (N_i + \tfrac{1}{2})$$

where $\hbar$ is Planck's constant divided by 2π, and N_i is an integer quantum number indicating the excitation level of the oscillator.

Next, to obtain the proper form of the Helmholtz free energy, F, another murky realm must be consulted, that of statistical mechanics. The form of F is found to be

$$F = kT\sum_{i=1}^{3N} \ln\left[2\sinh\left(\frac{\hbar\omega_i}{kT}\right)\right]$$

where k is Boltzmann's constant, and T is temperature.

CONCLUSIONS

So if you are a believer, it is now apparent that an explicit form for the vibrational free energy of a crystal lattice may be obtained in terms of the frequencies of the oscillators to which the motion has been reduced. Close observation of the equation above indicates, however, that since the sum goes over about 10^{23} oscillators, differentiation of F term by term could be a rather lengthy process. The problem of expressing 10^{23} frequencies in terms of strain, even for our simple model, could also be a big problem. For these reasons a final approximation must be made. This is, in effect, to replace the ω_i's by an average oscillator frequency $\overline{\omega^2}$. This procedure eliminates both problems mentioned above since we now need deal with only one frequency, $\overline{\omega^2}$, which may be expressed as

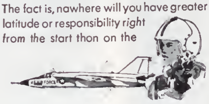
$$\overline{\omega^2} = \frac{1}{3N}\left[\frac{\partial^2 V}{\partial x_1^2} + \frac{\partial^2 V}{\partial x_2^2} + \frac{\partial^2 V}{\partial x_3^2}\right]$$

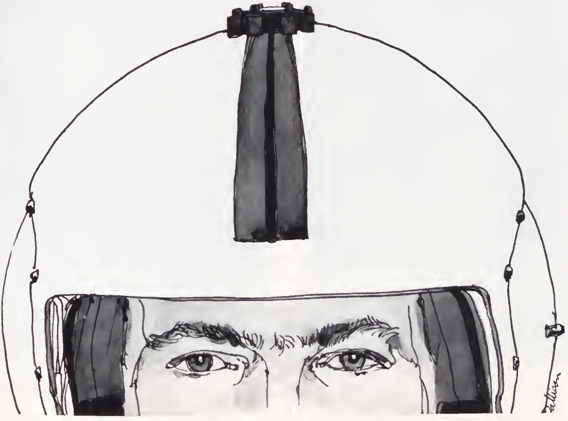
where the x,y,z now refer to the three coordinates of a single atom. This result is fortunate indeed since, from the vibration chaos and abstract coordinates, we have been brought back to an expression in terms of the lattice potential energy which is easily interpreted in terms of atomic interactions.

Retracing the discussion, we first saw that the Helmholtz free energy must be found and differentiated in order to obtain elastic constants. Next, a static model was introduced and it was indicated how one might find the elastic constants at absolute zero temperature. In order to introduce temperature the model was allowed to vibrate and the vibrational free energy of the model was sought. By a purely classical coordinate transformation, the lattice vibrations were then reduced to those of 3N independent harmonic oscillators. Finally, by employing quantum mechanics, statistical mechanics, and an average oscillator frequency it was indicated that the vibrational energy could be expressed in terms of strain as desired; and nothing was left but differentiation to obtain the elastic constants.

A great deal of detail has admittedly been omitted and many inherent problems neglected in the discussion. The purpose of the article, however, is not thereby hampered because it was intended only to convey an awareness and appreciation of an exciting and intriguing area of engineering research. It is hoped that this purpose has been achieved.


U.S. AIR FORCE





FACTS AND FIGURES: ENGINEERS' WEEK 1966

The value of the program presented during Engineers' Week is difficult to determine. For some people the event was a worthwhile experience; to others it was simply one more thing to be endured; and to a third group it was interesting and informative but left no lasting impression.

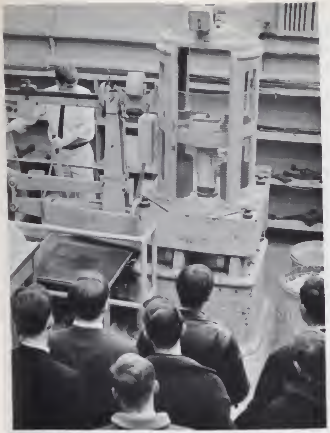
Participation was on a very broad base. This year twenty-two companies and agencies sent displays and literature to the School. The Engineer Alumni Association entered the program by presenting an excellent open forum on the subject of engineering practice. Prominent men from Jansky and Bailey, COMSAT, PEPCO, Frank J. Sullivan Associates, and the National Academy of Sciences were the panelists. The Engineers' Council, Theta Tau, Tau Beta Pi, Sigma Tau, ASCE, ASME, IEEE provided able assistance as guides and as demonstrators. The special edition of MECHELECIV was prepared with the aid of the editor, Millard Carr. Everyone who was willing, or who could be persuaded, had the opportunity to help out.

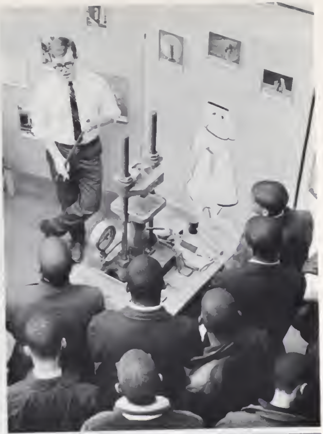
The Public Relations Office of the University flooded the news media with information about the event. Invitations to tour the School went to 225 high schools in the area and to 650 science clubs in Maryland, Washington, and Virginia. Nearly 1,000 students and club members attended, and judging by their comments, they were duly impressed by the School and by the engineering students they met.

It is all over now for one more year. There are many facets of the program which could be improved. Suggestions are always welcome. Address them to the Engineers' Week Chairman of the Engineers' Council and leave them in the D-H House mail box at 731 Twenty-second St.

EDITOR'S NOTE:

Mecheleciv would like to publicly thank Mr. Douglas Lowe for all his work in making Engineers' Week a success. The Special Engineers' Week Mecheleciv issue was due, almost entirely, to Doug's efforts. It is this publication's feeling that if the School of Engineering continues to graduate students of Doug's ability and drive, it may make some contribution to the engineering profession after all.



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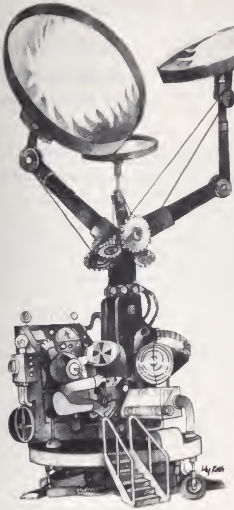
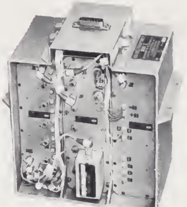


Flash it with a sun mirror . . .



. . . or command it through a Motorola Transponder*

THE PROBLEM: HOW DO YOU TELL THE SPACECRAFT TO MAKE A LEFT TURN ON ITS WAY TO MARS?

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MOTOROLA

Mr. Jerry L. Edwards is a full time graduate student working in the Metrology program under an N.S.F. Engineering Traineeship. Jerry was editor last year and was in his undergraduate years, Regent of Theta Tau and Chairman of A.S.M.E. as well as a commissioned 2nd Lt. in the U.S.A.F. from the R.O.T.C. program.

A MODERN VIE

AND ITS APPLICATION TO THE PROBLEM OF ALLOY PHASE STABILITY

Because materials science is a quantitative study of the properties of materials, one of the fundamental problems of the subject is predicting how those properties change when the material is subjected to a change in environmental conditions. For example, engineers would like to predict how the length of a rod changes when a uniaxial force is applied to it, or how the magnetic susceptibility of an alloy changes under high pressure, or how the distribution carbon within a steel changes with temperature. All of these problems can be treated in a similar manner as follows. For every set of environmental conditions such as temperature, pressure, mechanical stress, electrical field intensity, etc., there exists a particular state of the material which is stable under those conditions. Such a state, sometimes called an equilibrium state, is considered stable if there is no tendency for the material's properties to change their values with time.

As all property changes in a material must obey the principles of thermodynamics, these principles can often provide the key for predicting the stable states mentioned above. The author feels that the power of thermodynamics has not been fully utilized in materials science because its principles are not usually expressed in the most suitable form for such applications.

It is the purpose of this paper to briefly review a rather modern formulation of thermodynamics and apply it to one particular problem -- the chemical stability of alloy phases under various conditions of temperature, pressure, and chemical composition.

Classical thermodynamics was developed at a time when the atomic theory of matter was still in question. And today it is still taught to students in basically the same way. Fortunately, the situation is changing. In most of the recent books on thermodynamics, there is a chapter or two on statistical mechanics, but such chapters never seem to be fully integrated with the rest of the book. The really fundamental relationship between statistical mechanics and the second law of thermodynamics is not emphasized the way it should be. The quantum theory of matter and its relationship to thermodynamics is not usually even mentioned.

A more up-to-date approach to thermodynamics might well start right off with the Boltzman entropy relation

$$S = k \ln W \tag{1}$$

and from statistical mechanics make use of the fact that the probability W associated with a particular distribution of N particles on a set of quantum mechanical energy levels can be expressed as a function of the total energy E and N; i.e.,

$$W = f(E, N) \tag{2}$$

or, in the case of a mixture of more than one kind of particle, we would find

$$W = f(E, N_1, N_2, \cdots) \tag{3}$$

And from quantum mechanics, we learn that the spacing of the energy levels, and therefore W, is also a function extensive variables such as the volume V, the area A, the electric field intensity $\vec{E}$, the components of the strain tensor Σ_{ij}, and so on. Thus we can write, in general that

$$S = k \ln W = S(E, V, N_1, N_2, \cdots, A, \vec{E}, \Sigma_{11}, \Sigma_{12}, \cdots) \tag{4}$$

(A relationship such as this is used by Callen [1]* as a basis for his treatment of thermodynamics. He arrived at this equation, however, in a somewhat different manner.)

The above functional relationship (4) giving entropy in terms of a set of extensive variables is enough. For from it, all of the relations of classical thermodynamics can be derived in an efficient and elegant manner. To begin to see this, assume that we solve a simplified form of (4),

$$S = S(E, V, N_1, N_2, \cdots) \tag{5}$$

for E:

$$E = E(S, V, N_1, N_2, \cdots) \tag{6}$$

Then by taking the total differential, we have

$$dE = \left(\frac{\partial E}{\partial S}\right)_{V,N_i} dS + \left(\frac{\partial E}{\partial V}\right)_{S,N_i} dV + \sum_i \left(\frac{\partial E}{\partial N_i}\right)_{S,V} dN_i \tag{7}$$

Now by an appropriate set of definitions for temperature T, pressure P, and chemical potential μ_i, equation (7) becomes

$$dE = T\,dS - P\,dV + \sum_i \mu_i\,dN_i \tag{8}$$

With this and the statistical mechanical knowledge that S approaches a maximum value, Callen derives all the equilibrium relations of classical thermodynamics such as temperature equality between systems separated by a diathermal wall and pressure equality between systems separated by a flexible wall.

Furthermore, Callen introduces the enthalpy function H, the Helmholtz free energy function A, and the Gibbs free energy function G by using Lagrangian Transformations and arrives at equations such as

$$G = G(T, P, N_1, N_2, \cdots) \tag{9}$$

which contains all the information that equation (5) does but uses the more convenient variables

*Numbers in brackets refer to references at the end of the paper.

OF THERMODYNAMICS

by Jerry L. Edwards

T and P. Also, he shows that G tends to a minimum rather than a maximum value as does S.

With the requirement that S is maximum, i.e., $d^2S < 0$, Callen goes on to discuss the stability thermodynamic systems and derives "some of the most interesting and significant predictions of thermodynamics." [1] However, rather than discussing these and other results of Callen's treatment, in this paper we will instead apply the principles of thermodynamics to the metallurgical problem of phase equilibrium in alloys.

Consider an alloy system composed of n different metal elements, with N_i moles of the i^{th} element. To simplify the following argument, we suppose that the alloy is composed of only two solid phases, α and β. Let N_i^α and N_i^β be the number of moles of the i^{th} element in the α and β phases, respectively, such that

$$N_i^\alpha + N_i^\beta = N_i \qquad (10)$$

Usually it is more convenient to use the mole fraction

$$x_i^\alpha = \frac{N_i^\alpha}{N_i} \quad ; \quad x_i^\beta = \frac{N_i^\beta}{N_i}$$

Then equation (10) becomes

$$x_i^\alpha + x_i^\beta = 1 \qquad (11)$$

This has the advantage of reducing the number of independent variables by one. The alloy system can be divided into two subsystems, one for each phase. The total Gibbs free energy can be thus written as a sum:

$$G = G^\alpha(T, P, x_1^\alpha, x_2^\alpha, \cdots) + G^\beta(T, P, x_1^\beta, x_2^\beta, \cdots) \qquad (12)$$

In writing this we are assuming that T and P are constant and are the same for both phases which is nearly always the case in metallurgical problems. If the alloy system is not in phase equilibrium, then the distribution of the elements (the values of x_1^α, x_2^α, ... , x_1^β, x_2^β, ...) will spontaneously change until G takes on a minimum value. Thus at equilibrium dG = 0.

From equation (12), with constant T and P, we have

$$\begin{aligned} dG &= \sum_i \mu_i^\alpha dx_i^\alpha + \sum_i \mu_i^\beta dx_i^\beta \\ &= \sum_i (\mu_i^\alpha dx_i^\alpha + \mu_i^\beta dx_i^\beta) \end{aligned} \qquad (13)$$

From equation (11), we have

$$dx_i^\beta = -dx_i^\alpha$$

and on substituting this into equation (11) we arrive at

$$dG = \sum_i (\mu_i^\alpha - \mu_i^\beta)\, dx_i^\alpha = 0 \qquad (14)$$

This can be true for all possible infinitesimal changes in the x_i^α away from their equilibrium values only if

$$\mu_i^\alpha = \mu_i^\beta \qquad (15)$$

So the chemical potential of the i^{th} element must be the same in both phases if G is to be minimized and the alloy to be in equilibrium. If $\mu_i^\alpha > \mu_i^\beta$, then since dG must be negative, dx_i^α must also be negative; that is, the i^{th} element must be leaving the α phase and entering the β phase.

We now have a method of solving the problem of chemical stability of alloy phases. We must determine a set of chemical potential functions, one for each phase and one for each element:

$$\mu_i^\alpha = \mu_i^\alpha(T, P, x_1^\alpha, x_2^\alpha, \cdots, x_{n-1}^\alpha) \quad \text{for each i,}$$

$$\mu_i^\beta = \mu_i^\beta(T, P, x_1^\alpha, x_2^\alpha, \cdots, x_{n-1}^\alpha) \quad \text{for each i,}$$

and so on for each phase.

If there are m phases, then there are m(n-1) + 2 unknowns in the above set of equations. But there will in general be n(m-1) equations such as equation (15) which can be used to solve for these unknowns. We thus arrive at the very important Gibbs phase rule where f is the number of "degrees of freedom."

$$f = [m(n-1) + 2] - [n(m-1)]$$

or

$$f = n - m + 2$$

From this we see that we can solve for the complete distribution of elements among the phases; i.e., the values of x_1^α, x_2^α, ..., x_1^β, x_2^β, ...; for a given T and P only if n=m. Note also that since $f \geq 0$, we must have $m \leq n + 2$.

The difficulty with the above "solution" is that chemical potential functions cannot be readily determined experimentally. So it is the practice to introduce a new variable by comparing the properties of the real solutions (or phases) being considered with ideal ones. This new variable is the activity of the i^{th} element in a given phase defined by

$$a_i = \frac{P_i}{P_i^o} \qquad (16)$$

where P_i is the vapor pressure of the i^{th} element over the phase and P_i^o the vapor pressure of the i^{th} element in a pure state. These vapor pressures are exceedingly small for solids, of course.

Since, by definition, an ideal solution is one for which

$$P_i = P_i^o x_i \qquad (17)$$

where x_i is the mole fraction of the i^{th} element

(Continued on page 18)

in the solution, we have

$$a_i = x_i \qquad (18)$$

for an ideal solution. From statistical mechanical considerations, it can be shown that equations (17) or (18) can be true only if there is no interaction between the different components in the solution. (See, for example, Wall [2]).

Now to see the connection between activity and chemical potential, we make use of the relation

$$G = RT \ln P$$

which is derived in elementary thermodynamics for the ideal gas. For a gas mixture, this becomes

$$\mu_i = RT \ln P_i \qquad (19)$$

which is a very important relation in chemical thermodynamics. It makes it quite easy to write the equations for equilibrium in a system of reacting ideal gases. It can be used for solids, if we assume that the vapors over the solids are ideal gases which is usually nearly true. For the pure element

$$\mu_i = RT \ln P_i^\circ \qquad (20)$$

Subtracting equation (20) from (19), we find

$$\begin{aligned} \mu_i - \mu_i^\circ &= RT \ln P_i - RT \ln P_i^\circ \\ &= RT \ln \frac{P_i}{P_i^\circ} = RT \ln a_i \end{aligned} \qquad (21)$$

This establishes the desired relationship. By subtracting from both sides of equation (15), we have

$$\mu_i^\alpha - \mu_i^\circ = \mu_i^\beta - \mu_i^\circ$$

From this and equation (21), we see that

$$a_i^\alpha = a_i^\beta$$

must hold it two phases α and β are to be in equilibrium with respect to the transfer of the i^{th} element between those phases.

For the ideal solid solution, equation (21) becomes

$$\mu_i - \mu_i^\circ = RT \ln x_i \qquad (22)$$

For a non-ideal solution $a_i \neq x_i$ and a dimensionless quantity known as the activity coefficient γ_i is usually defined.

$$\gamma_i = a_i / x_i \qquad (23)$$

The reason for this definition is that values of γ_i are easier to tabulate than those of a_i.

It is important to realize that a_i and thus γ_i are, in general, functions of temperature, pressure, and composition and must be determined from experimental measurements. After introducing one more concept which is useful in the experimental determination of activity functions, we will briefly discuss some of methods for these determinations.

Consider the formation of a solution. (The formation of compounds is usually developed in terms of a "reaction potential" $\Delta\tilde{G}$ and an equilibrium constant K. See Wall [2]).

$$N_1A_1 + N_2A_2 + \cdots \rightleftharpoons [N_1A_1 + N_2A_2 + \cdots] \qquad (24)$$

Where A1, A2, ... denote pure elements; N1, N2, ... denote the number of moles of these elements; and [N1A1 + N2A2 + ...] denotes the solution. ΔG for (24) is given by

$$\begin{aligned} \Delta G &= N_1\mu_1 + N_2\mu_2 + \cdots - N_1\mu_1^\circ - N_2\mu_2^\circ - \cdots \\ &= N_1(\mu_1 - \mu_1^\circ) + N_2(\mu_2 - \mu_2^\circ) + \cdots \end{aligned} \qquad (25)$$

Combining this with equations (21) and (23) yields

$$\Delta G = \sum_i N_i RT \ln a_i \qquad (26)$$

and

$$\Delta G = \sum_i N_i RT \ln x_i + \sum_i N_i RT \ln \gamma_i \qquad (27)$$

For an ideal solution, denoted by an asterisk, the activity coefficients of all constituents are equal to unity and the second term on the right-hand side of equation (27) vanishes:

$$\Delta G^* = \sum_i N_i RT \ln x_i \qquad (28)$$

The difference ΔG-ΔG^* for real solutions is called the excess free energy ΔG^{EX} in the literature.

$$\Delta G^{EX} = \Delta G - \Delta G^* = \sum_i N_i RT \ln \gamma_i \qquad (29)$$

By partial differentiation with respect to the moles of any element i, we obtain

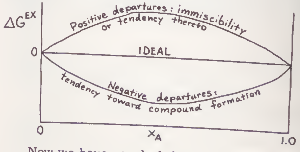
$$\begin{aligned} \left(\frac{\partial \Delta G^{EX}}{\partial N_i}\right)_{T,P,N_j} &= RT \ln \gamma_i + RT\left[N_1 \frac{\partial \ln \gamma_1}{\partial N_i} + N_2 \frac{\partial \ln \gamma_2}{\partial N_i} + \cdots\right] \\ &= RT \ln \gamma_i \end{aligned} \qquad (30)$$

since by an important relation, called the Gibbs-Duhem equation, which is derived in most books on chemical thermodynamics ([2] for example), we have

$$N_1 \frac{\partial \ln \gamma_1}{\partial N_i} + N_2 \frac{\partial \ln \gamma_2}{\partial N_i} + \cdots = 0 \qquad (31)$$

The importance of ΔG^{EX} lies in the fact that ΔG can often be determined experimentally and ΔG^* is, of course, known, so equation (29) provides a means of obtaining the activity as a function of the composition of the solution.

Another reason why ΔG^{EX} is important is because, by definition, an ideal solution is one in which no net interaction between atoms occurs. The excess free energy reflects the type of interaction that occurs. This is illustrated by the following graph which is similar to one presented by Darken and Gurry [3]. They used a quantity slightly different from the ΔG^{EX} used here, however.



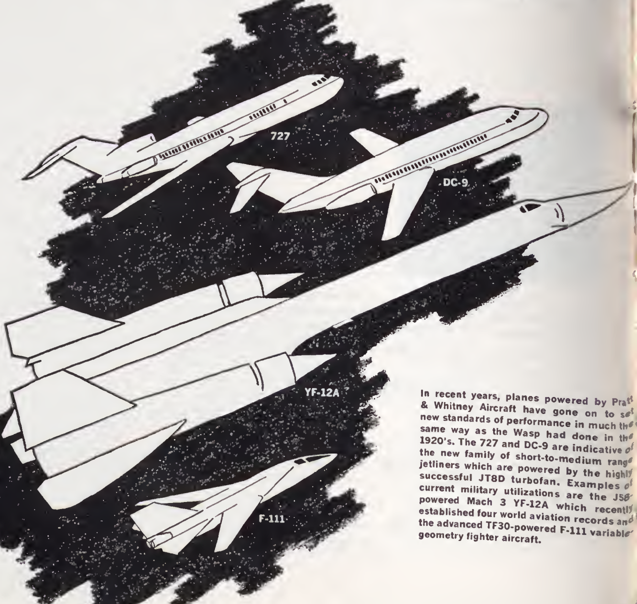
Now we have reached the point where we can solve the problem of phase stability in alloy systems (and derive phase equilibrium diagrams) if

(Continued on page 38)

Past

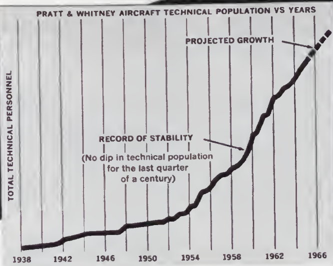
The Company's first engine, the Wasp, took to the air on May 5, 1926. Within a year the Wasp set its first world record and went on to smash existing records and set standards for both land and seaplanes for years to come, carrying airframes and pilots higher, farther, and faster than they had ever gone before.

Present



In recent years, planes powered by Pratt & Whitney Aircraft have gone on to set new standards of performance in much the same way as the Wasp had done in the 1920's. The 727 and DC-9 are indicative of the new family of short-to-medium range jetliners which are powered by the highly successful JT8D turbofan. Examples of current military utilizations are the J58-powered Mach 3 YF-12A which recently established four world aviation records and the advanced TF30-powered F-111 variable-geometry fighter aircraft.

Your and ~~the~~ Future



Take a look at the above chart; then a good long look at Pratt & Whitney Aircraft—where technical careers offer exciting growth, continuing challenge, and lasting stability—where engineers and scientists are recognized as the major reason for the Company's continued success.

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MECH MISS . . .

Miss Shirley Snyder

This month's Mech Miss is Shirley Snyder, a delightful 18 year old sophomore beauty majoring in American Thought and Civilization. Shirley enjoys skiing, canoeing, swimming, and traveling. She has lived in Pakistan, Afghanistan, Kenya, Ivory Coast, Switzerland, Malawi, Mexico, and Lebanon, and she speaks three languages.

Here at GWU, she works in the book store, is a member of the ski club, and was on the Homecoming Queen's Committee. Maybe some engineer needs help in geography.

DIRY NTRY:

by Judith J. Popowsky

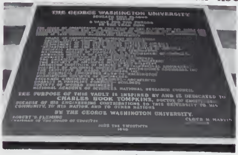
Editor's Note:

While investigating the many splendored wonders of the elaborately equipped M.E. lab, Miss Popowsky discovered a rather crudely constructed (even for the M.E. lab) complicated, metallic box labeled "TIME MACHINE fall semester 1959". Inside this obviously undergraduate M.E. project she found a small diary, written in a cryptic scrawl and bound in artificial Moroccan leather (the artificial Moroccan has yet to be developed by modern technology). Diligently translating the strange language, using a rather advanced mathematical approach, Miss Popowsky has given us what may be a contribution of far reaching historical portent. An excerpt appears below.

Judith Popowsky is one of the few distaff students to be successful in the School of Engineering and Applied Science. She expects to graduate in June of 1966 with a B.S.M.E., having been extremely active by holding all the major offices on the Engineers' Council and the Mecheleciv staff. She has also been active in IEEE and has been elected to Sigma Tau, Who's Who and several other honor societies.

"Diry Ntry: Jun 21, 2056

I am plesed. We hav, at last, fownd one that is ntact. (Dr. Morga was afrad wen it was opend. So many hav ben dstroyed by owygen lekes. We wer relikwishing hop that any had survived.) We wil cal it the Tompkins Vault, that it miit be set diferent from the Washington (Time) Vault fownd by Kraal and his asosiats.



Jun 22, 2056

This must be the vault dscribed by Ikos, in his disertation on the probabl number of vaults buried by pepl of a teknikal bakrownd, as having ben located at a centr of lerning, in wat was ons the centr of govrnment for the now non-xistent United States of America. Ther ar many itms of litratur, wich Morga has takn to desifer, and others mekanikal in natur, wich I hav ben givn to xamin."

Jun 23, 2056

The traslations ar copleted. We hav fownd, to mi singular delit, that many of the documents prtain to the mekanikal objets wich Morga has ntrusted to me. (Kraal and a copanon, Zurak, whom I belev to be the sam Zurak fownder of the Los Angeles Vault, hav com to help Morga compil the aditions to his ditionary; aditions of words and frases takn from the newspaprs, periodicls, and articls of a non-teknikal natur takn from the Vault.)

Jun 24, 2056

The mekanikal objets wer spred own on a tabl for me this morning. It seems I hav akwired an abl asistat in this man who cals himself Uras. (Perhaps he wil be the one to tran for taking mi position. He seems nteligent enoff, and wat holds mor mportance, he is nterested in mi work here.) We xamined them closly, using primarily the Petrsburn Tests and Calibrativ Procedures. I am afrad that Morga has a grat shok coming to him. These 'ancient ones', as he cals them, of the past sentury wer abl to produs mashined tools to an xseptional degre of tolerans and akurasy. This 'gyroscope' and these 'strain gauges' ar, with the xseption that the metl used is of a weker, les kohesiv kwality, ekwal to objets of similar use today! Now, he CANNOT cal them barbans.*

I wish ther wer mor evidens of how much progres they mad toard motionles mekanisms. The fotografs Morga shoed me ar of mashines and other objets, som of which probably contan motionles sektions; but to wat degre the ntir mekanisms ar of a non-moving natur I do not noe. (I must mention, in passing, that ther wer ..." "... other fotografs, primarily of lokations arownd the site of the Vault. Many of them ar duplicats of fotografs fownd in past vaults; but a few, mainly thos in the periodicls themselvs, ar new to Morga and the othr historians now with him, xamining the documents of the Tompkins Vault.

Jun 25, 2056

Al of the mekanikal objets from the Tompkins Vault hav now ben tiped. They wil soon be shiped to the museum in Norkaan-Tonn. I must konfes that I hav witheld one of the riting mplements. It has a very fin point, and glids smoothly ovr the papr. Ther is but a singl problm: it lekes."

*barbans: barbarians

RELAXATIO

Ricardo Nieto was born on February 28, 1942, in Colombia, South America. He finished high school in Colombia in 1960, and he has been attending GWU since Fall, 1961. While working for his B.S.E.E., Ricardo finds the time to be an active member in the Theta Tau Fraternity. His future plans include studies towards a Masters degree in communications.

INTRODUCTION

It is known that regenerative feedback is to be avoided in an amplifier if stability is to be obtained. If the circuit is provided with a sufficient amount of regenerative feedback, it will serve as a periodic wave generator. The generator output may be a sinusoidal wave; or a square wave, hence of high harmonic content. Or it may be periodically recurring, though of general nonsinusoidal shape.

A large variety of feedback circuits, which differ considerably in detail, are available for the production of self-sustained oscillations. In each case, a feedback circuit exists through which a portion of the output is fed back to the input circuit, resulting in self-excitation. In the usual case of a tube, the feedback from the output to the input circuit is accomplished externally by means of coupling networks.

TYPES OF OSCILLATORS

Conventional self-excited oscillators for the production of sinusoidal waves operate as class C devices. Class A oscillators, which incorporate amplitude controlling schemes, are also possible and find extensive use in certain applications. Another class of oscillators, known as relaxation oscillators, operate over such a wide amplitude range that the tube is cut off over a substantial portion of the cycle. Conventional oscillator considerations are no longer applicable in this latter type, as the operation is of a recurring transient character rather than one where there is an energy transfer from output to input circuits during an appreciable portion of the cycle.

The relaxation oscillator, like the feedback oscillator, is provided with a feedback loop. However, in the case of a feedback oscillator, the amount of feedback is usually adjusted such that a sinusoidal output results. In the relaxation oscillator, the feedback is large, so large that the tube is driven beyond cutoff. The tube remains off for a time determined by the time constants of the grid circuit, after which the grid recovers control of the circuit. Because of this operation, a distorted output results. But, such a distorted output wave is rich in harmonics and may be used as a harmonic source. More often, however, these devices produce waveshapes that have direct applications. Among the important relaxation oscillators are the multivibrator, a device that produces a square wave in the output; the blocking oscillator, a device that produces narrow pulses, and the sweep oscillator, a device that produces a sawtooth wave in the output.

THYRATRON: A GAS FILLED TRIODE

A thyratron is a gas filled, grid controlled tube in which an arc discharge between cathode and anode is initiated by thermoionic emission of electrons. A thyratron is used essentially as a switch, since the tube operates in either the conducting or non-conducting state. During conduction, the plate-cathode voltage is low (10-20 volts) and is constant over the normal current range. The current that flows in the plate circuit is determined by the voltage applied to the circuit and the impedance of the nonconducting state by maintaining the grid voltage at a negative value. The critical value of the grid voltage which marks the transition to the conducting state is a function of the plate voltage (cutoff voltage). An increase in plate voltage requires that the grid voltage becomes more negative to prevent conduction.

Fig. 1 — Critical Grid Voltage Characteristics of an 884 Thyrotron.

The grid voltage cannot alter the magnitude of the plate current during conduction, and, therefore, cannot produce plate current cutoff. The

OSCILLATORS

by Ricardo Nieto

plate current is reduced to zero by reducing the plate voltage to a value below the tube cutoff voltage. Figure 1 gives the relationship between grid voltage and plate voltage which will cause the tube to fire. The tube will remain in the nonconducting state provided the grid voltage lies to the left of the curve, for a given plate voltage. When the tube is approached from the left, the tube conducts and the plate voltage drops to a low value which is independent of the grid voltage. The curve shown in figure 1 is typical for thyratrons that use a gas such as neon, argon, helium or hydrogen.

OSCILLATORS AND THE THYRATRON

After giving this brief explanation of the operation of the thyratron the understanding of relaxation oscillators which use this tube will be easier. It should be remembered that while a hot cathode gas-filled tube is conducting, the tube voltage drop remains constant at a low value (10-20 volts). If the voltage is dropped below this value, or if the current is reduced to a low value, deionization will occur, and the current will finally drop to zero. Once deionization has taken place, conduction cannot be initiated again except by raising the anode potential above the cutoff voltage.

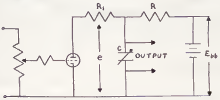


Fig. 2 — Arc Tube Relaxation Oscillator.

Figure 2 shows a circuit diagram of a typical sweep oscillator. The capacitor C is charged exponentially through the resistor R until the capacitor voltage Vc becomes large enough to cause the tube to begin conducting. The capacitor is then discharged through the tube and R_1 to a voltage below which the discharge arc will be extinguished. Once this point is reached, the capacitor can no longer provide a current in the tube without further loss of voltage. As a result, the remaining current in the tube is just that which flows through the resistor R. If R is large, this current will not maintain ionization and the current through the tube will finally drop to zero. The capacitor is then charged, and the cycle is repeated. The resistor R_1 is a current limiting resistor to keep the peak discharge current within safe limits. If R_1 is too small, the tube will be damaged. If the charging resistor R is too small, it will pass enough current at the end of the discharge portion of the cycle to maintain ionization in the tube. This will prevent the extinction of the arc, and the cycle will not be repeated.

WAVE FORMS

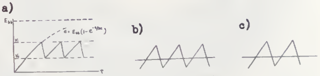


Fig. 3a) Correct Operation
Fig. 3b) V_i/E_{bb} too High
Fig. 3c) R_i too Large

Figure 3 shows the waveform of the capacitor voltage. V_i and V_e are the ignition and extinction voltages, respectively, for the given grid bias. V_e is essentially constant for any given tube, between 10 and 20 volts. V_i may be adjusted over wide limits by adjusting the grid bias. Figure 3 shows that if a V_i is a small fraction of E_{bb}, the portion of the exponential charging curve which is used in forming the sawtooth is a good approximation of a straight line. If V_i is slightly less than E_{bb}, the portion of the sawtooth waveform is no longer linear (see fig. 3b). The discharge through R_1 is also exponential in waveform, but since R_1 is small, it can usually be considered as being nearly instantaneous. If R_1 is too large the discharge time is no longer negligible, and a waveform is distorted (fig. 3c).

(Continued on page 28)

RELAXATION OSCILLATORS—Continued from page 27

The time to charge the capacitor is found to be:

$$T = RC \ln \frac{E_{bb} - V_e}{E_{bb} - V_e}$$

If the discharge time is negligible compared to the charging time, the frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1}{RC} \ln \frac{E_{bb} - V_e}{E_{bb} - V_e}$$

In practice E_{bb}, V_e, and V_i are held constant so that the waveform and amplitude are constant, and the frequency is adjusted by R and C. The sawtooth can be synchronized by an A-C signal that is some multiple of the sawtooth frequency. This is done by applying the synchronizing wave to the grid of the tube.

THE UNIJUNCTION TRANSISTOR

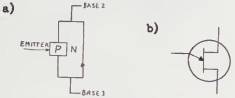


Fig. 4a) Construction of the Transistor.
Fig. 4b) Symbol to Represent the Unijunction Transistor.

The unijunction transistor is a device that can be used in the production of the sawtooth waveform. It consists of a bar of N type material which has a P type grown somewhere near the center of the bar (see fig. 4). This junction can then act as a P-N diode. The regions between the base contacts and the P-N junction have certain resistivities which depend on the charge carriers in these regions. These resistances are shown in figure 5 as R_{b1} and R_{b2}.

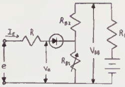


Fig. 5 — Equivalent Unijunction Transistor in a Typical Circuit.

When a voltage V_{bb} is applied, a current will flow between base 1 and base 2. R_{b1} and R_{b2} then act as a voltage divider so that a fraction of the applied voltage, μ V_{bb} will appear across R_{b1}. μ is the intrinsic stand-off ratio, and is the ratio of R_{b1} to R_{b1} plus R_{b2} i.e.

$$\mu = \frac{R_{b1}}{R_{b1} + R_{b2}}$$

If the emitter voltage, V_{e1} is originally small the P-N diode will be reversed biased and I_e will be nearly zero. If e is made positive, such that V_e is larger than the voltage across R_{b1}, the P-N junction will be forward biased and holes will be injected into the N region. This increase of hole density in the region from base 1 to the emitter junction causes an increase in the electron density since the electrons move to neutralize the excess positive charge (holes). This movement causes R_{b1} to drop and I_e increases rapidly while V_e decreases rapidly. Thus, the unijunction transistor acts a negative resistance device when switched on.

THE UNIJUNCTION TRANSISTOR AS AN OSCILLATOR

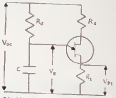


Fig. 6 — Unijunction Transistor Used as a Relaxation Oscillator.

Figure 6 shows a unijunction transistor used as a relaxation oscillator. The capacitor C will charge, exponentially, through the charging resistor R_3. At a certain value of V_e, the unijunction transistor will fire and provide low resistance discharge path for the capacitor. When V_e is low enough (approximately 2 volts) the P-N junction will again become reversed biased, and the transistor will turn off. The cycle will then repeat. During the time the capacitor is discharging through the transistor, a positive pulse will appear across R_1. Thus, the circuit in figure 7 will act as a sawtooth generator (waveform across C) and a pulse generator (waveform across R_1).

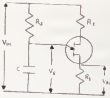


Fig. 7

In obtaining any desired output, the unijunction transistor is usually preferred over the thyratron tube. With the thyratron, the supply voltage and grid voltage are usually held at some fixed value leaving only the charging resistor and capacitor as parameters. With the transistor, there are three resistors and one capacitor that can be adjusted to give the desired output. The transistor thus provides greater design flexibility.

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BC + VOFFAFF = ΘTF

(Business Conference + Victory over Freezing Flurries and Fickle Flirts = THETA TAU FRATERNITY)

by Doug Lowe

January 28-31, 1966 We Were There!

We were 13, an unlucky number. The snow came. We were 8. Our mission was to reach Raleigh, N. C. in time to present a report on operations of the Washington unit (code: GAMMA BETA CHAPTER) Jump-off time was 1000 on Friday, January 28. Weather report was O.K., road conditions O.K., equipment O.K., Systems Go. (Buckled up for safety!)

Bruce and Norm took off down 95 in the Jag. Chip and Bob followed in the VW. Joe -- well, Joe went cross-country, thinking his Falcon was a snowmobile. We closed formation in the first 60 miles and pulled into checkpoint Richmond for some K-burgers. Contact was established with Raleigh to report our progress. We proceeded rapidly southward and split up to approach Raleigh from three directions. Actually, we zigged when we should have zagged.

Following orders, we located quarters at a nondescript downtown inn with a heated outdoor swimming pool. The Jag men searched out the local pub and, in the best form of GWU students, found the longest possible way to the nearest restaurant. By flickering candlelight we ate the steak and observed the walking jail-bait. . . Steadfast in purpose and ever-mindful of the important Regional Conference to be held on Saturday, we returned to the inn to finish preparations. However, all work and no play makes ΘT's dull, so some of the troops trooped out to be sharpened. Needless to say they were bright-eyed and bushy-tailed at breakfast.

Promptly at 0900 the Conference began. The GWU unit joined those from Columbia University (THETA), Syracuse University (TAU) and host, North Carolina State (RHO) in very timely and informative round table discussions. Unit operational and recruiting procedures were examined in depth. Work proceeded well into the evening. Monkey business was next on the agenda after old and new business, so the meeting was recessed and resumed at a dinner and dance with some of those delectable Southern belles, Mech Misses, all. (Strictly in the line of duty, mind you.) Adjournment at the stroke of twelve did not mean the end of a hard day's night. In line for more duty and eager to be resharpened, some GAMMA BETA troops trooped again. Their devotion above and beyond was amazing, and also noticeable early Sunday morning when they got up in the afternoon.

Meanwhile, reports from D.C. told of impassable roads due to the Blizzard of '66. Unperturbed, the units successfully concluded the Conference, with their spirits raised still higher, and bid hasty farewells. GAMMA BETA headed north -- again the Jag out in front, then the VW, then the Falcon with a different navigator this time. Tense but alert and daring, we pushed on. The miles passed quickly as day became night.

Then -- WIPEOUT! Scratch one Jag. (Ever wonder how it feels to tunnel into four feet of snow at 60 miles per hour after being run off the road?) That wasn't bad enough; the Jag men left the anti-freeze in the glove compartment.

We squeezed into the two remaining cars and headed out once more. At Springfield, Shirley Highway ended, even for the snowmobile. Taking off into the back country, we pushed, plowed, and prayed our way into Howard's Roost. Bruce's parents were lucky: they had the rare opportunity of providing for 8 unexpected guests who arrived hungry. No longer were we on a mission: we were tired, cold and starved. Hot chili and coffee at one o'clock in the morning could not have tasted better.

Monday morning we set out to recover the anti-freeze and the Jag. ΘT's strongly recommend 4 wheel drive!

Was this whole story really a lot to do about nothing? No -- far from it.

Books contain only a fraction of the knowledge needed by any student who hopes to be a successful engineer some time in the future. Theta Tau tries to impart to its members some of the remainder of this necessary knowledge by presenting programs to develop what might be called the professional facets of the engineer, as opposed to those of a technical nature. The Regional Conference which GAMMA BETA attended was fun, naturally, but it also had the purpose of conducting a serious business. We accomplished a great deal and learned much, both as a group and as individuals.

Look around School. You will find many Theta Taus. Theta Tau is definitely not an honor society; rather, it is a professional fraternity of engineering students who are trying to prepare themselves for satisfying, successful, and rewarding careers, and lives.

Chip Young can give you more information. Call 481-1763.

THETA TAU

GAMMA BETA SPARKS A CONFERENCE DISCUSSION.

REGENT CHIP YOUNG AND BROTHER DOUG LOWE RECEIVE THE MAN-MILE PLAQUE.

THE MAN-MILE PLAQUE, BEING EARNED ...

THESE HIGH, LEVEL CONFERENCES SURE TAKE A LOT OUT OF A FELLA

Ford Motor Company is:

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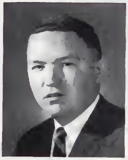

Larry Moore
B.M.E., Univ. of Kansas

The college graduate's initial exposure to the world of business is often less than exhilarating. The reason? A great many companies require the recent graduate to serve a long-term apprenticeship in a role that offers little or no opportunity to demonstrate personal capabilities. That is not the way at Ford Motor Company. Our College Graduate Program brings you into contact with many phases of business, encourages self-expression and helps you—and us—determine where your greatest potential lies. An important benefit of the Program is getting to know and work with some of the most capable people in industry. One of many young men who believes he has gained tremendously from this exposure and experience is Larry Moore, a Product Design engineer.

After receiving his B.M.E. in February, 1964, Larry joined our College Graduate Program and began work in brake design. Stimulating assignments followed in product evaluation and disc brake development. Later, he learned production techniques while supervising one phase of the Mustang assembly line operations. An assignment in our Truck Sales Promotion and Training Department added still another dimension to his experience. The "big picture" of product development was brought into focus for Larry when he became associated with Thunderbird Product Planning. From there he moved to the Special Vehicles Section . . . into the exciting world of high-performance cars!

Currently, Larry Moore is on leave of absence, studying to acquire his M.B.A. degree at Michigan State. He feels—and rightly so—that we're 100 percent behind his desire to improve his educational background. Young men with talent, initiative and ambition can go far with Ford Motor Company. Think about it—and talk to our representative when he next visits your campus.

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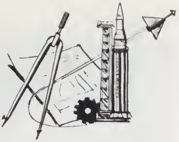
TECH NEWS



MICROWAVE DIODES

A tiny solid-state device that makes possible low-cost, lightweight microwave energy systems for use in communications, safety, space and defense applications has been developed by Sylvania Electric Product Inc.

The device, called a MOD (Microwave Oscillating Diode), shown below with a dime, will permit weight reductions of up to 98 per cent in microwave power sources. It also eliminates virtually all of the heat created in present microwave generators using low-power klystrons or magnetrons.

The MOD is about the size of a sharpened point of a pencil. It is the first commercially available microwave semiconductor device which is guaranteed to provide a specified level of microwave power output when excited by direct current.

The MOD represents a significant breakthrough that eventually will lead to the practical use of low-cost microwave energy in small, lightweight packages. Such uses could include radar systems to "dock" spacecraft at satellite stations; automobile and boat collision-control units; missile tracking systems; TV transmission between orbiting spacecraft, and devices to track aircraft during landing approaches.

First applications of the new diode could be in low-cost lightweight microwave communications systems for use in schools or hospitals. The feasibility of such a system has been proven and a laboratory model of a microwave communications system for short-range transmission of TV signals has been developed.

The equipment used to generate the microwave signal is only 1/50 the weight of present commercially available systems and virtually eliminates all of the destructive heat formerly associated with such equipment.

BATTERIES WITH TEN LIVES

The nuclear fuel that heated the sodium that boiled the water that made the steam that turned the turbine that powered the generator that produced the power that Jack used may have company. University of Illinois researchers in nuclear engineering are working on two simple processes which convert nuclear energy directly to electric power.

The first device, called the "fission electric cell," is shown in Figure 1. One electrode is coated with a thin layer of fissionable fuel such as uranium. Fission occurs in the fuel layer when it is bombarded by neutrons, and some of the fission fragments escape the layer, cross the vacuum gap, and strike the other electrode. Since each fragment is positively charged, a voltage potential (sometimes as high as millions of volts) builds up between the two electrodes. This high-voltage, low-amperage power would be useful for operating space engines, microwave radio equipment, or other instruments.

Fig. 1

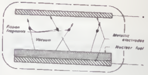
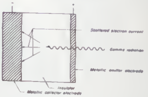


Fig. 2



Simpler in construction, the "gamma cell" produces electric energy from gamma radiation. As Figure 2 shows, the cell consists of a gamma ray source, two metallic electrodes, and a separating insulator. Gamma rays emitted from the source scatter electrons in the insulator, pushing them to the collector electrode, which accumulates a negative potential relative to the emitter electrode. The emitter and collector thus become the electrodes of a high-voltage power supply.

Neither device is likely to replace the flashlight battery. Those who are conducting the research, caution that the fission electric cell is far from perfected. Although tests have been run elsewhere, studies of this cell so far have been limited to theoretical investigations by the complexity and expense of the equipment necessary for its operation.

Because of its relatively low efficiency as a power converter, this cell will probably find use as a power-salvaging shield for space reactors.

The most promising aspect of this research, of course, is that it may lead to the development of a truly efficient nuclear-electric energy source capable of powering electric rockets to distant parts of the universe, providing power for isolated or fuel-poor communities, or satisfying the mushrooming power demands met today by a diminishing supply of natural energy sources.

THIN FILM MODEL

Scientists of IBM have found that by rolling different sized balls into an inclined tray, they can duplicate what happens when atoms from hot metallic vapors are frozen directly onto a cold surface.

The model is the first to give such complete insight into how different metal atoms group together to form thin alloy films. Such films are fabricated for study and possible use in advanced electronic circuitry. Because they are made by depositing metals directly from a vapor, without going through a liquid stage, they do not follow the traditional rules of metallurgy. The model provides an excellent means of achieving a deeper understanding of this new area of metallurgy.

The following conclusions can be drawn from the model, all of which are in qualitative agreement with observations of the behavior of thin films:

1. As the rate of deposition is increased, the grain size decreases.

2. Spheres of the same size produce a "crystalline" structure, even for rapid deposition rates. Vibration "annealing" then produces considerable grain growth and elimination of imperfections within the grains.

3. Dilute "alloys" show a finer grain size in the as-deposited state than do the spheres of only one size. Furthermore, "annealing" upon vibration is slower and less extensive for the case of alloys.

4. For concentrated "alloys" composed of two sets of spheres differing in size by 27 percent, amorphous structures are obtained in the composition range 30-70 percent. Amorphous structures cannot be obtained at any compositions for alloys composed of spheres differing in size by less than 14 percent.

5. When an amorphous structure is deposited, it generally remains amorphous after vibration "annealing", although an increase in density occurs. This is a consequence of the fact that the log jam in the structure cannot be relieved by vibration.

6. The structure obtained on a "crystalline" substrate depends on the rate of deposition. For rates below some critical value (called the epitaxial rate) one obtains essentially an epitaxial structure, whose perfection improves on annealing. Above this rate, one obtains a polycrystalline structure, which becomes better defined, but remains polycrystalline, upon annealing. This epitaxial rate is not sharply defined.

7. The presence of impurities which differ in size from the substrate periodicity lowers the epitaxial rate.

LETTERS TO THE EDITOR

MECHELECIV is once again surprised and gratified to have received two letters To-The-Editor. Let's hope this obviously cathartic trend continues.

To the Editor:

I enjoyed reading the thoughts of our faculty published in your special Engineers' Week edition of MECHELECIV. Those statements provide us all with much needed insight as to the ideals and objectives of our school. However, one of the consequences of the public expression of ideals is that the public naturally starts to compare the ideals with the practice. That is what this letter is about.

First, I will give you my necessarily biased impression of the educational practice here at G.W., an impression which is based on seven years of study in the School of Engineering. (The "Applied Science" was added when I was finishing up my B.S. degree.) When I have done that, I will be so bold as to offer suggestions both to the faculty and to the student for bringing the practice more in line with the ideals.

The major emphasis in the education process here is placed on the successful completion of an uncoordinated series of lecture courses, the content of which can often be picked up in perhaps 20 or 30 hours of intensive "cramming" just before the final exam. In his courses, the student is given only a minimum amount of laboratory and library research work. The laboratory work that is required is usually rushed and thus tends to be superficial. The occasional research paper which the student must complete just before finals is rarely thoughtfully criticized and returned by the instructor. In too many courses, professors attempt to teach too much technical information in too little depth.

The result of this type of education is painfully evident. First, only a tiny fraction of the information presented in the lecture courses is remembered by the student simply because he has little time to "inwardly digest" all that he is taught. That is, he cannot integrate the content of current courses with past courses; he cannot separate the important concepts from the less important; he cannot, as Professor Arkilic says, "comprehend the significance" of what he is taught because he is swamped with so-called "fundamental knowledge."

Secondly, the type of work which the student is assigned results in only superficial understanding and thinking. In fact, I sometimes feel that the student is not expected to think at all; he is expected only to "learn." Is our school really a place "for experiencing adventures of the mind and of the hands; for the formulation, exchange, and exploration of ideas" as the 1966-67 Bulletin so proudly says on page 13. Is the student "led to strengthen his skills in analysis and his talent for creative activity, through liberal use of project-type laboratory work?" Is it true that "independent thought and original ideas receive higher evaluation, in the appraisal of student achievements, than the rote recital of information" as the School's Bulletin further asserts? My answer to these questions is emphatically NO!

Finally, the ideal of "a lifetime student" was stressed in MECHELECIV's special issue both by Professor Arkilic and by Professor Robinson. However, the University could very well be discouraging lifetime study by unconsciously associating education with "taking courses," by constantly treating the student as if he were incapable of acquiring knowledge by himself through independent study.

This ends my critique. If I am wrong, I certainly don't mind being told so; if I am right, then there must be better ways to achieve our School's professed objectives. My own recommendations for increasing the educational efficiency of the School of Engineering and Applied Science are as follows:

1. Recall the words of Alfred North Whitehead -- "The students are alive, and the purpose of education is to stimulate and guide their self-development." His whole book, The Aims of Education, "is a protest against dead knowledge, that is to say, against inert ideas."

2. Let each instructor clearly state in specific detail all important objectives of each course and its relationship to other courses. This would help students so much in understanding and remembering what they are taught.

An Engineering Education?

3. Make greater use of the "course syllabus" and the "reading list" to guide the student's independent study both before and after graduation.

4. Dispense with mandatory class attendance, and allow for individual differences in the way each student best learns. Grade students on how well, rather than how, they master course objectives.

5. Emphasize the importance of thorough work and clear analytical thinking by a few well-chosen and well-graded engineering reports requiring both laboratory and library research, extending over at least a two semester period. Have those reports rewritten until minimum standards of good writing and clear thinking are met.

6. More clearly state in writing the minimum skills and knowledge required for graduation. Then let the faculty spend more time and effort in designing effective comprehensive examinations and study outlines to insure that those requirements are met.

Now my recommendations to the student are simple. NEVER LET THE UNIVERSITY INTERFERE WITH YOUR EDUCATION. Take to heart the words of Dean Mason who in his letter to MECHELECIV said: "If I had it to do over -- I'd be a different student than I was. I'd search diligently for ways to find out more . . . than I did. I'm sure I would rebel against the professor who repeated the text in class, or who considered my assumed brains to be a sponge, or who didn't make me think . . . , or who didn't treat me as responsibly as he demanded I treat him. (Incidently I know now the secret way to rebel -- I'd quietly learn more on my own about the subject than I knew and then start a discussion in class.)"

In one way or another, let's make sure we get the education we are paying so much for!

/s/ Jerry L. Edwards

Dear Editor:

Judy's article, "You Have Got To Be Kidding" in many ways described a situation very similar to my own. I guess all girl engineering students are asked the very same questions over and over again. However, Judy's statement, "One such [aspect of engineering] is my being the only girl in my classes since my sophomore year (engineering classes, that is)" is not quite true. If Ap.S. 5 can be considered an engineering course, as I believe it can, then Judy should glance around the room someday and notice that she is not the only girl.

/s/ Karen Spindel

. a protest against dead knowledge . . ."

Dear Karen:

It is gratifying to have our glances filled with something besides an equation now and then. Keep up the good work and if you need any help matriculating, don't hesitate to contact. . . .

the editor

—Continued from page 18

we have the necessary experimental data. This data is a set of activity functions:

$$a_i^\alpha = a_i^\alpha(T, P, x_1^\alpha, x_2^\alpha, \cdots, x_{n-1}^\alpha)\ ,$$

$$a_i^\beta = a_i^\beta(T, P, x_1^\beta, x_2^\beta, \cdots, x_{n-1}^\beta)\ ,$$

one for each element and one for each phase. Three of the most important methods of obtaining this data will now be outlined. These and other methods are discussed in the book by Hultgren, et al [4], which is also probably the best compilation of thermodynamic data on metals and alloys to date.

A. E.M.F. MEASUREMENTS

If a suitable electrolytic cell can be constructed, then a_i can be determined from

$$\mu_i^B - \mu_i^\circ = RT \ln a_i^B = -n \mathcal{F} \mathcal{E}_B$$

where $\mathcal{E}_B$ is the voltage between an electrode composed of pure B and one composed of the alloy $A_{1-x}B_x$. a_i^B can be determined as a function of temperature if $\mathcal{E}_B$ is so measured. The E.M.F. technique is, however, normally useful at relatively low temperatures. Also the cell must be a reversible one, and this usually is quite a problem.

B. VAPOR PRESSURE MEASUREMENTS

If one of the components is relatively volatile, then measurement of the equilibrium vapor pressures, P_i and P_i^o, give the activity directly.

$$a_i = P_i / P_i^\circ$$

However, measurement of such very low vapor pressures is very difficult. Methods using radioactive tracers, briefly described by Leymonie [5], appear promising in this regard.

C. CALORIMETRIC MEASUREMENTS

As mentioned before ΔG for the formation of a solution can be measured. It must be done in two steps. First, ΔH data must be obtained by the use of a solution calorimeter. Then, ΔS is determined by heat capacity measurements. These results are combined to find

$$\Delta G = \Delta H - T\Delta S$$

from which ΔG^{EX} and the activity functions are found by the methods described previously.

In summary, we have shown how phase equilibrium problems can be solved using activity function data, assuming such data is available. One of the applications of this data is the construction of phase equilibrium diagrams, which otherwise can only be constructed using the methods of thermal analysis. These methods often tend to result in incorrect diagrams because of errors due to super-cooling, segregation, and insufficient data.

We have in no way exhausted the possible uses of modern treatments of thermodynamics in materials science. For example, by including the area in the free energy function, equation (9), we can solve such problems as the equilibrium grain size in alloys. This problem is discussed by Swalin in his book [6]. As another example, by including the components of the strain tensor in the free energy function, we might be able to better understand such things as the martinsite transformation where strain energy becomes important.

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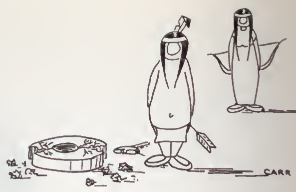
THE SHAFT



Scene: A field hospital in Viet Nam. A correspondent is talking to a soldier bandaged from head to foot. The correspondent eager for the gruesome details asked for the soldier's story.

"It's a long story," said the soldier. "When I first got here I was told how to recognize friend from foe. I was told when I came upon a man to yell 'Ho Chi Minh is a rat!' and if he smiles, he's a friend and if he gets angry he's a foe, and I was to shoot him. Well, I was here for about six months and then as I was walking along this jungle road, I saw a man. With my gun at the ready, I yelled, 'Ho Chi Minh is a rat.' But he did not smile or get angry. Instead, he cupped his hands and yelled 'Lyndon Johnson is a fink.' And as we were shaking hands in the middle of the road, a truck ran over me."

* * *

We'd have less trouble in this country if the Indians had had stricter immigration laws.

* * *

A drunk was doing his best to spear an olive with a toothpick. Time after time the olive eluded him. Finally a man nearby became annoyed, took a toothpick and said, "This is the way to do it," and speared the olive on the first try.

"Sure, sure," replied the drunk, "after I got him so tired he couldn't get away."

* * *

M.E.: I think she's priceless.
E.E.: I know she is.

* * *

The inebriated university professor staggered into the bar and asked the bartender for a dry martinus.

"Beg your pardon, sir," the bartender replied, "but do you mean a martini?"

"Now see here, my good man," exclaimed the 90-proof prof. "If I want two, I'll ask for them."

The young kindergarten teacher had just instructed her charges to come forward as their names were called and be prepared to draw something on the blackboard that had been the cause of excitement in their homes during the previous week. One by one the pupils came forward and sketched such items as report cards, television sets, mothers' new hats, and the like. When it came time for Johnny, the class cutup, to comply with the assignment, however, he walked to the board and simply made two white chalk dots before returning to his seat. Suspecting that he was up to one of his usual pranks, the teacher advised Johnny that he had better be able to explain why those two dots were exciting if he didn't want to be kept after school.

"Well," said Johnny, "the other day you told us that those dots are also called periods---"

"That's correct, the teacher interrupted. "But what could possibly be exciting about two periods?"

"Beats me," replied Johnny, "But that's how many my sister in high school says she's missed, and they're causing an awful lot of excitement around our house!"

* * *

Tell me, Tommy," the elderly schoolmarm inquired of one of her fifth-grade students, "if you started with twenty dollars and gave seven of them to Nancy, five to Mary and eight to Judy, what would you then have?"

"A ball!" answered Tommy.

* * *

Possibly man could live twice as long if he didn't spend the first half acquiring habits that shortened the other half.

* * *

Federal aid is like giving yourself a blood transfusion in your left arm, drawing from your right arm and spilling 90 per cent of it on the way across.

Most people have some sort of religion--at least they know which church they're staying away from.

* * *

Then there was the M.E. who thought that steel wool was the fleece from a hydraulic ram.

* * *

During an out-of-town business trip, the young executive picked up a lovely creature in the hotel bar and took her up to his room for a nightcap. After a few drinks, the girl sat on his lap and cooed, "Would you like to hug me?"

"Sure," said the businessman, pressing her close to him.

"And would you like to kiss me?" the girl whispered passionately.

"Of course," he replied, planting a big buss on her inviting lips.

"O.K. honey" she continued. "Brace yourself--because here comes the fifty-dollar question."

* * *

Two Indian scouts watched silently from their place of concealment behind some shrubbery as the first white settlers set foot on the North American continent. After solemnly surveying the scene for several minutes, the one Indian turned to the other and said, "Well, there goes the neighborhood."

* * *

The human tongue seems to run faster when the brain is in neutral.

* * *

A young lady after a broken engagement returned all the gent's letters marked, "Fourth Class Male."

* * *

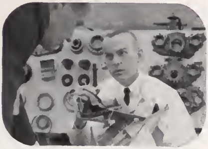
Love is like a fried egg. Looks pretty at first, but the moment you take a stab at it, it becomes a big mess.

* * *

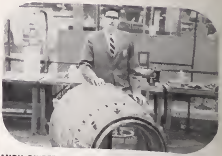
The percentage of alcoholics in the United States is staggering.

SIX G-E J93 ENGINES push USAF XB-70 to MACH 3.

JACK WADDEY, Auburn U., 1965, translates customer requirements into aircraft electrical systems on a Technical Marketing Program assignment at Specialty Control Dept.



PAUL HENRY is assigned to design and analysis of compressor components for G.E.'s Large Jet Engine Dept. He holds a BSME from the University of Cincinnati, 1964.



ANDY O'KEEFE, Villanova U., BSEE, 1965, Manufacturing Training Program, works on fabrications for large jet engines at LJED, Evendale, Ohio.

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Achieving Thrust for Mach 3

When the North American Aviation XB-70 established a milestone by achieving Mach 3 flight, it was powered by six General Electric J93 jet engines. That flight was the high point of two decades of G-E leadership in jet power that began when America's first jet plane was flown in 1942. In addition to the 30,000-pound thrust J93's, the XB-70 carries a unique, 240-kva electrical system that supplies all on-board power needs—designed by G-E engineers. The challenge of advanced flight propulsion promises even more opportunity at G.E. GETF39 engines will help the new USAF C-5A fly more payload than any other aircraft in the world; the Mach 3 GE4/J5 is designed to deliver 50,000-pound thrust for a U.S. Supersonic Transport (SST). General Electric's involvement in jet power since the beginning of propellerless flight has made us one of the world's leading suppliers of these prime movers. This is typical of the fast-paced technical challenge you'll find in any of G.E.'s 120 decentralized product operations. To define your career interest at General Electric, talk with your placement officer, or write us now. Section 699-16, Schenectady, N.Y. 12305. An Equal Opportunity Employer.

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